国际先进煤技术应用交流会议

The International Advanced Coal Technologies Conference

Summary Report

June 3-7, 2012

Xi'an, Shaanxi Province, People's Republic of China

SPONSORED BY:

2012 International Advanced Coal Technologies Conference

Summary Report

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Introduction

The 2012 International Advanced Coal Technologies Conference (IACTC) was held June 3-7, 2012 in Xi'an, Shaanxi Province, People's Republic of China. The conference was hosted by the People's Government of Shaanxi Province and the State of Wyoming and co-sponsored by the University of Wyoming School of Energy Resources (SER), Shaanxi Provincial Development and Reform Commission (SPDRC), Northwest University (NWU), Shaanxi Provincial Institute of Energy Resources and Chemical Engineering (SPIERCE), the University of Wyoming Carbon Management Institute (CMI), and the American Consortium of Sino-U.S. Clean Energy Research Center (ACSUS-CERC). The conference was held at the Sofitel Convention Center in Xi'an and conference field tours took place Yulin, a city in northern Shaanxi Province. Approximately 128 participants attended the event, including 23 Wyoming-based government leaders, scholars, and stakeholders and 12 University of Wyoming students.

Purpose and Background

The purpose of the 2012 IACTC conference was to advance the goals set forth by the U.S. - China Clean Energy Research Center (CERC) which was established in November 2009. The overarching goal of CERC is to (CERC, 2011):

> Facilitate joint research, development, and commercialization of clean energy technologies between the United States and China … while building a foundation of knowledge, human capabilities, and relationships in mutually beneficial areas that will emphasize clean energy in both nations.

The U.S. – China Clean Energy Research Center maintains three focus areas for collaborative research and development. Advanced coal technologies, including carbon capture, storage, and utilization is one of the three CERC focus areas. The group appointed to lead the U.S. CERC efforts is the U.S. Advanced Coal Technology Consortia (CERC-ACTC), which is managed by Dr. Jerald Fletcher of West Virginia University. The vision put forth by the CERC-ACTC is to "advance the coal technology needed to safely, effectively, and efficiently utilize coal resources including the ability to capture, store, and utilize emissions from coal use in both nations" (CERC, 2011). Furthermore, CERC seeks to actively manage and protect intellectual property rights and any new discoveries that should arise from the collaborations. To date, CERC-ACTC has experienced successes in the development of various advanced combustion technologies like chemical looping, oxy-combustion, catalytic gasification of coal, and co-conversion of coal with biomass.

The first international conference bringing together U.S., Chinese, and Australian stakeholders pursuant to the CERC effort took place in Queensland, Australia in 2008. The subsequent conference was held in Laramie, Wyoming in 2010. This is the third international conference.

Conference Overview

The International Advanced Coal Technologies Conference in Xi'an opened Sunday, June 3, 2012 with a news conference featuring Wyoming State Governor Matthew H. Mead, Shaanxi Provincial Government Governor Zhao Zhengyong, and top officials from both Shaanxi and Wyoming. The news conference served as a platform for formal introductions and provided Governors Mead and Zhengyong the opportunity to exchange remarks regarding the intent of the conference and the advancement of the collaborative relationship between the State of Wyoming, and Shaanxi Province. The news conference was followed by a formal signing ceremony for "Developing Sister-City Relations between Shaanxi Province of China and the State of Wyoming, U.S." (Find a copy of the "Sister-City Relations" document in Appendix A).

On Monday, June 4 and Tuesday, June 5, conference attendees heard 28 presentations from research scientists, government leaders, industry and policy stakeholders, and academics from the United States, China, and Australia. Approximately 125 people attended the conference, 72 attending from the Chinese delegation (For a conference attendee list see Appendix B). A significant number of students attended the conference, including 12 University of Wyoming undergraduate and graduate students.

Central topics of conference presentations:

- Coal to liquids (CTL) for transport fuels, advancements in technologies and application experiences
- Advancements in coal gasification technologies
- Advancements in coal-to-chemical and coal-to-liquid technologies
- Advancements in carbon capture and sequestration technologies
- Advancements in mitigating pollutants in pre- and post- combustion operations
- Advancements post-combustion capture (PCC) technologies
- Advancements in Cryogenic Carbon Capture™ technologies
- Energy efficiency opportunities in coal applications
- CO_2 mitigation using microalgae
- Integrated utilization of coal, oil, and natural gas for chemicals, fuels, other materials
- Water reduction measures
- Improving processing control systems
- Improving conversion rates

The field tour component of the IACTC took place on Wednesday, June 6 and Thursday, June 7 in the energy-rich city of Yulin. Field tour participants visited a variety of coal to fuels and coal to chemical conversion facilities around the outskirts of Yulin.

News Conference, Sister-State Agreement, and Sister-City Agreement Signing

Sunday, June 3, 2012

The IACTC opened with a news conference followed by a formal signing ceremony of Sister-State and Sister-City agreements. The Sister-State Relations agreement was signed by Governor Mead and Governor Zhengyong. The Sister-City Relations agreement was signed by Tom Murphy, mayor of the City of Gillette, Wyoming and Zhiyuan Lu, mayor of the City of Yulin, Shaanxi Province.

During the news conference Governor Mead and Governor Zhengyong exchanged opening remarks regarding the intent of the conference and the advancement of the collaborative relationship between Wyoming and Shaanxi Province. The governors were joined by these regional leaders : Zheng Qing, vice secretary general of Shaanxi Provincial Government; Zuoli Zhu, director of Shaanxi Provincial Development and Reform Commission; Zhang Baowen, director of Shaanxi Provincial Foreign Affairs Office; He Fali, director of Shaanxi Provincial Environment Protection Department; He Jiuchang, deputy director of Shaanxi Provincial Development and Reform Commission; Lu Zhiyuan, mayor of Yulin; Fang Guanghua, president of Northwest University; Bob Grady, economics advisor to Governor Mead; Mark Northam, director of UW School of Energy Resources; Ron Surdam, director of the Carbon Management Institute; Kari Jo Gray, chief of staff, Governor's Office, State of Wyoming; State Rep. Thomas Lubnau II, House Majority Floor Leader; and Shawn Reese, policy director, Governor's Office, State of Wyoming among others.

The leaders described their governing regions as relying heavily on natural resources as well as tourism and agriculture. Governor Mead noted that Wyoming is eager to capitalize on attracting diversified economic opportunities that utilize natural resources from a value-added approach. Both governors agreed that continuing to build on the relationship between the State of Wyoming and Shaanxi Province will be beneficial in many ways, both now and into the future.

Opening Remarks by Governor Zhao Zhengyong

Summary

Governor Zhengyong expressed his sincere gratitude to Governor Mead and the Wyoming delegates for making the trip to their province, noting that personal relationships help to build trust and provide a more open opportunity for knowledge exchange and business collaboration. Zhengyong said that the Shaanxi Province, with a population of approximately 37 million (Xi'an with approximately 8.5million), is a leader among Chinese provinces with respect to higher education opportunities. There are more than 100 institutions of higher education in Shaanxi Province (20 being private institutions) with

roughly 1.2 million students enrolled and graduating 250,000 students a year (many of whom are in engineering and other science-related majors). Governor Zhengyong said his government is eager to attract economic development to the region to provide high-level employment opportunities for local graduates.

Governor Zhengyong also said Shaanxi Province has been a leader in China in applying the most advanced coal technologies in the country. The provincial government is determined to continue leading the country in technological innovation and research.

Opening Remarks by Governor Matthew H. Mead

Summary

Governor Mead expressed his gratitude to all those attending as well as to the event organizers and hosts, noting its importance to Shaanxi, Wyoming and the world.

Governor Mead provided details about his family's Wyoming heritage and ranching culture and described Wyoming's wealth of natural resources. He emphasized Wyoming's energy resource portfolio noting that in the United States, Wyoming is first in uranium reserves, first in coal production, first in trona production, first in bentonite production, first in helium production, and second in natural gas production. Governor Mead also pointed out the importance of agriculture and tourism to Wyoming's economy and stressed the value of Wyoming's healthy environment, national parks, and wildlife. Balancing Wyoming's energy economy with environmental stewardship, according to Mead, is of great importance to the State of Wyoming and its residents.

Governor Mead discussed the importance of advancing technologies in all arenas -- coal, oil, gas, wind, solar, nuclear, hydro- power, among others, noting that with respect to coal, he is confident that cleaner, more efficient uses for the abundant resource will be found. "Finding energy solutions is not just about our economies, which we all have in common, finding energy solutions is ultimately about how we can provide a better life for our citizens, about taking care of our children, our parents, and our planet."

In his conclusion Governor Mead said he is excited about all energy sources, but growing energy demand requires developing newer, better technologies and uses for coal.

OVERVIEW OF PRESENTATIONS

Exploring the Low Carbon Development Path for Coal Resources Comprehensive Utilization

Presentation Summary

Zhu Zuoli, director of the ShaanXi Provincial Development and Reform Commission, provided an introduction to Shaanxi Province's natural resources. He emphasized the ample natural resources found in the Ordos Basin. The Ordos Basin alone accounts for 43 percent of the coal resources available in China. Shaanxi has focused its most recent efforts on six categories. These categories are:

- Classified Utilization: Removing impurities of coal, reducing ash, sulfur and phosphorus contents, and classifying coal by quality
- Multi-Level Utilization: Promising method for low-rank coal, coal catalytic decomposition, coal tar hydrogenation technology of low-medium temps, joint production of coal pyrolysis, gasification, and electricity generation
- Integrated Utilization: Utilizing coal, oil and natural gas; utilizing carbon hydrogen complementing to increase methanol conversion rates, which has been shown to reduce CO_2 emissions by 65 percent and water use by 50 percent; lignite and heavy oil co-processing
- Electricity Generation: Increased efficiencies in transmission and strategic location of coal mines and generating facilities
- Coal to Liquids (CTL): Utilizing technologies with low reaction temperatures and low pressures
- Coal to Chemical Industry: Coal to olefins and methanol to olefins facility, first of its kind in the world

Zuoli said Shaanxi Province is committed to building world-class and domestic leading high-end industrial zones with an improved level of supporting infrastructure. He emphasized the great value he sees in advancing coal research and technologies and the opportunity for knowledge sharing. Environmental protections and water security were also listed as a high priority for the province moving forward. He concluded by saying Shaanxi Province is committed to achieving low-carbon development through efficient use of resources and sustaining the provincial economy through a diversified and comprehensive use of the region's coal resources.

Carbon Capture: Opportunities and Obstacles

Presentation Summary (Keynote)

James Wood, deputy assistant secretary, Office of Clean Coal, U.S. Department of Energy, discussed the obstacles and possible opportunities for China and the United States in developing feasible carbon capture and storage (CCS) technologies. He noted the

growing pressures on both countries to reduce carbon emissions from the combustion of fossil fuels and emphasized the great challenge that CCS has posed on researchers. With the growing demand for low-carbon energy sources, especially in the United States, Wood highlighted that finding a low-cost and reliable CCS technology is critical to the future of coal. In describing the challenge posed by CCS development, Wood said:

> Unlike the cost effective advanced technologies that were developed to reduce emissions of nitrogen, sulfur, mercury and particulates, technologies to capture and store carbon emissions from electric power plants are elusive, expensive and, although there are CO2 separation technologies in use in the natural gas and chemical processing industries, there has not yet been widespread deployment in the electric power industry, and there is little history of the integration of these technologies with electric generation in reliable or cost-effective modes.

The manufacturing sector in both China and the United States are highly reliant on affordable electricity. Carbon capture projects that use existing infrastructure will be important. Even if the United States and China were able to find a low-cost, reliable CCS technology and begin implementing it in a reasonable timeframe, Wood said it may be too late to favorably affect climate change. Improving public acceptance of CCS technologies may be beneficial in moving CCS technology development and deployment forward.

Wood discussed areas of potential cooperation between the private and public sectors in the United States and China and why cooperation could lead to early deployment of de-carbonization technologies that would benefit both countries. The United States is a world leader in the utilization of CO_2 for the tertiary recovery of oil and China is a world leader in the gasification of fossil resources and the production of synthesis gas for manufacturing chemicals. The administration of President Obama has allocated $3 billion to co-sponsor with the private sector a portfolio of projects designed to demonstrate technologies for the capture of CO_2 from various industrial processes, including the combustion of fossil fuels, the production of ethanol and from steam methane reforming, and the integration of these capture technologies with CO_2 utilization and subsurface storage technologies. The DOE is hopeful that projects such as the FutureGen oxy-combustion project in Illinois and the Texas Clean Energy Integrated Gasification Combined Cycle (IGCC)-Polygeneration Project will be in operation by 2015. Getting these projects off the ground would provide the United States with a better understanding of the capital and operating costs, construction schedules, and emission reduction data to guide CCS programs forward. The DOE's goal is to have commercially available CCS technologies broadly available in the public sector by 2020-2025.

Wood described the public-private activities that are advancing technical solutions to carbon capture, use, and storage (CCUS). Among these, Wood said, is a co-operation between Duke Energy and Huaneng Power International to study the economics and technical performance of Huaneng's novel post-combustion capture technology. Furthermore, Southern Company, the largest public utility in the United States by

generation, is cooperating with the city of Dongguan to develop and demonstrate a new, proprietary gasification system based on transport reactor technology, which was co-developed with the DOE and which is especially effective in gasifying low rank, high moisture coals. This technology is under construction today at Southern Company's 600 megawatt Kemper County facility in northwest Mississippi. General Electric and Shenhua Group recently announced a joint venture called the GE Shenhua Gasification Technology Company, which combines the gasification and coal-fired generation experience of both companies to conduct research, develop cost reduction and performance enhancement strategies and to sell gasification licenses in China.

In conclusion, Wood reiterated the importance of the collaborative efforts of CERC and expressed his hope the group effort will lead to an economically feasible CCS technology.

Wyoming Energy Program Strategy – Investing and Collaborating for a Sustainable Energy Future

Presentation Summary

Dr. Mark A. Northam, director of the University of Wyoming's School of Energy Resources, presented information regarding the opportunities, challenges, and strategy for building a sustainable energy economy. Northam discussed how the University of Wyoming's School of Energy Resources is creating opportunities for collaborative research and development in the areas of low emissions coal technologies, CCS, exploitation of unconventional reservoirs, and value-added opportunities for natural gas and coal resources.

Following an introduction focused on the energy resource similarities between Shaanxi Province and the State of Wyoming, Northam pointed out a number of challenges currently facing Wyoming's energy economy. Wyoming's energy industry does not currently produce any significant amount of value-added products produced in-state from local resources; thus revenue fluctuations due to commodity pricing tend to lead to boom-bust and dig-and-ship patterns that are not conducive to economic stability.
Since the program's inception in 2006, SER has laid a solid foundation to begin addressing these challenges. To date, SER has created 11 distinguished professorships in seven departments across four colleges, supported more than 100 graduate assistants to conduct energy research, established eight Centers of Excellence to develop energy research programs across multiple disciplines, matched funds to assist faculty in capturing important grants for energy research, created a $60 million research program across broad areas of advanced coal technology including gasification and synthesis gas cleanup, catalyst development, and CCS patents, and supported the drilling of a deep well to assess CO_2 storage at a potential commercial site The priorities of SER will focus on:

1) research and development of technologies related to exploiting unconventional reservoirs [i.e. tight gas, shale gas, shale oil, and residual oil zones]
2) researching and developing new technologies in refining, conversion, and other manufacturing activities that will add value to energy resources otherwise sold as commodities and create new markets for these resources
3) advance research and development in the renewable energy fields of wind and solar, specifically technologies that improve efficiency, mitigate intermittency, and convert output of renewable energy resources to higher value products.

Low Emissions Coal Technology in Australia

Presentation Summary

John Carras, director of CSIRO Advanced Coal Technology, discussed the Australian government's active role in developing low-emissions coal technologies in coordination with industry stakeholders and the Australian research community. The Australian government's Clean Energy Initiative is supporting demonstration-scale low emissions technologies through the CCS Flagship Program. Australia also has a partnership with China through the Asia Pacific Partnership Program on Clean Development and Climate and the Australian-China Joint Coordination Group on Clean Coal Technology. He described the efforts of the recently formed Australian National Low Emissions Coal (ANLEC Research & Development) and Brown Coal Innovation Australia (BCIA) group that will provide a strategic focus on low emission coal research for both brown and black coal.

Several notable projects are under way in Australia, which are applying advanced coal technologies, including the South West Hub CCS Flagship Project, the Chevron Gorgon LNG Project, the Delta CCS Demonstration Project (2013-2015 scheduled start), the Callide Oxyfuel Project (CS Energy, estimated start 2015), and the CO_2 CRC Otway Project. Through these projects, researchers are focusing on opportunities to improve post-combustion capture by using improved solvents, integrating processes to increase overall efficiency and lower energy penalties, and limiting overall emissions from PCC technology. In the transportation of CO_2, CSIRO is focusing on improving properties of the gas mixtures from generation and capture processes. Furthermore, on the storage end of CCS, the group is focusing on improving methods for monitoring and verifying deep saline formations with computer models to calculate and predict movement, behavior, and fate of injected CO_2 (tracers, surface geophysics, downhole geophysics, and sensors).

Carras discussed CSIRO's efforts related to mitigating fugitive emissions of methane which currently account for about 6 percent of Australia's greenhouse gas (GHG) emissions. To mitigate these fugitive emissions, which arise from both surface and underground mines, CSIRO has developed a technology known as Ventilation Air Methane Catalytic Turbine™

(VAMCAT) to treat ventilated methane and reduce emissions. CSIRO is investigating pre-drainage at surface mines to mitigate methane emissions and methods for quantifying them.

Coal gasification and IGCC research has also been a focal point of research for CSIRO. Carras discussed the group's ongoing investigations of coal gasification reactions, mechanisms and kinetics as well as research in slag formation and flow, syngas cleaning and processing, gas separation (H_2/CO_2), and the research and development related to improving technology performance models.

Carras concluded by stating that Australia has an integrated program of research, development and demonstration (RD&D) in low emissions coal technologies ranging from fundamental scientific studies through to demonstration projects. Increasing the efficiency and reducing costs of clean coal technologies will play a key role in achieving long term greenhouse gas mitigation.

The Medicine Bow Coal to Liquids Project -- Coal to Transport Fuels and Carbon Capture and Sequestration in the United States

Presentation Summary

Robert Kelly, director of DKRW Advanced Fuels LLC, discussed the current market trends related to the coal-to-liquids (CTL) industry, noting that significant coal resources exist in the United States and abroad and demand for transportation fuel is steady and/or rising in much of the world. CTL technologies, principally ultra-low sulfur gasoline, can increase the value of coal.

DKRW's proposed Medicine Bow CTL facility in southeastern Wyoming is to be located on approximately 200 acres near the town of Medicine Bow in southeastern Carbon County. The project would be adjacent to the Elk Mountain Mine, a surface coal mine owned and operated by Arch Coal, Inc., and a 180 million ton underground coal reserve known as the Saddleback Hills Mine, also owned by Arch. The project would produce gasoline to be delivered to the Rocky Mountain Pipeline (RMP) Terminal in Cheyenne, Wyoming and then transported across the existing RMP pipeline, owned and operated by Plains All American, L.P., to the Dupont, Colorado terminal in the Denver area. The project has a secured buyer of the fuel for 25 years. Kelly also noted that 95 percent of the CO_2 produced by the project will be captured and be made available for enhanced oil recovery (EOR) purposes, which has significant revenue generation potential. Wyoming is currently short more than 800 million standard cubic feet per day (MMSCFD) of CO_2 for EOR and that there are 1,100 large oil reservoirs favorable for CO_2-EOR operations with potential reserves of 85 billion barrels. Kelly concluded by saying that CTL projects in today's energy markets have attractive returns if properly financed and securing key technologies and coal reserves early is important.

Advancements in Slurry Gasification

Presentation Summary

Jason Crew, general manager of Gasification and IGCC Products, GE Energy - Asia, provided background information on GE Energy's efforts in Asia and described the company's technological advancements in recent years relative to slurry gasification. GE Energy has 145 gasifiers in commercial operation -- the largest fleet in the industry – and it has 85 more gasifiers in design, engineering, or construction at 25 plants in 15 countries. The industry has experienced growth in China due to a number of factors including low-cost, flexibility, highly reliable technology, highly localized hardware and short build cycles of 36 months.

Crew described the differences and trade-offs between slurry-fed gasification and dry-fed gasification. Slurry-fed entrained flow gasification involves grinding and mixing coal with water and additives to form a slurry with typical concentrations between 55-70 percent. The benefits to slurry gasification include: 1) highly scalable pressure and throughput; 2) low cost and high reliability; and 3) highly flexible operating capability. The challenges to the slurry fed process include 1) traditional slurry preparation technology is not well suited for higher moisture coals, 2) it requires higher water consumption, and 3) it has a lower thermal efficiency. In contrast, Dry-Fed Entrained Flow Gasification involves grinding and conveying coal directly to the gasifier using advanced cooling systems to manage temperature and slagging. The benefits of dry-fed gasification include 1) higher thermal efficiency, 2) lower water consumption, and 3) suitability to use higher moisture coals, but the challenges include 1) throughput and pressure scale is costly and difficult, 2) the process has a higher capital cost and lower reliability, 3) the process has lower operating flexibility and is particularly sensitive to feedstock changes.

Crew noted several technological advancements GE Energy has made to improve its slurry gasification technology including improvements made to the control systems of the facilities.

GreenGen and CO_2 Capture Demonstration Projects

Presentation Summary

Xu Shisen, president of the China Huaneng Group Clean Energy Research Center, discussed the demonstration projects under construction by Shaanxi Coal and Chemical Industry Group. Shisen mentioned several projects under development and testing including a 3000 tons per acre (t/a) PCC thermal power plant in Beijing (first in China), a

120,000 t/a PCC coal plant in Shanghai (largest in world), an IGCC project, and the near-zero emissions GreenGen project.

The GreenGen project is supported by nine energy enterprises: China Huaneng Group, China Datang Group, China Huadian Corporation, China Guodian Corporation, China Power Investment Corporation, Shenhua Group, State Development and Investment Co., China Coal Group, and Peabody Energy. The objectives of GreenGen are as follows: 1) RD&D the integrated coal gasification, hydrogen production, hydrogen power generation and CO_2 sequestration system; 2) to achieve high coal-based generation efficiency and zero emissions for all pollutants and CO_2; 3) to master core and system integration technologies; and 4) to operate commercial demonstration economically and sustainably. Shisen highlighted several advanced components of the GreenGen project, including the potential capture and sequestration of 60,000 – 100,000 t/a of CO_2, fuel cell power generation technology, and improved IGCC polygeneration (power-heat-syngas) technology.

Post-Combustion Capture Technology Development for Australian Coal Fired Power Plants

Presentation Summary

Paul H.M. Feron, Research Program leader for CSIRO Energy Technology, discussed CSIRO's advancements in research and development of post combustion capture (PCC) of CO_2 technologies. The leading PCC technology for existing coal-fired power plants is based on a process that uses a liquid absorbent such as ammonia or another amine to capture and react with the CO_2 from the flue gases before it is emitted to the atmosphere. The resulting CO_2 product is of such purity that it is ready for compression, transport, and storage, yet existing PCC technologies are expensive and inefficient. CSIRO has several pilot projects currently in operation including the Loy Yang A Power Station PCC Pilot Plant in Victoria (2008), the Delta Electricity project (2009), the China Huaneng Project, and the Tarong Energy project (2010). These projects are testing a wide range of technologies including proprietary solvents, combined CO_2 and SO_2 control processes, emissions assessments, feasibility of aqueous ammonia, solar thermal energy for solvent regeneration, impact of flue gas impurities, and evaluations of other liquid and solid absorbents.

EAOC and industrial Service of Clean Coal Utilization

Presentation Summary

Yin Jian'an, chairman of the board and Senior Engineer for Shaanxi Blower Group Ltd., discussed the three central components to a clean coal utilization industry—clean coal utilization technology, efficiency analysis, and optimal-operation control and professional industrial services (EAOC). Shaanxi Blower Group has developed an EAOC or

professional industrial service that provides long-term "boarding" services to the construction, operation and maintenance of clean coal facilities.

Dow Chemical: A Growth and Sustainability Journey in China

Presentation Summary

Peng Ningke, deputy president of Dow Chemical in Greater China, explained that Dow Chemical is the second-largest chemical company in the world with annual sales of $60 billion in 2011. Dow supplies more than 5,000 products manufactured at 197 sites in 36 countries and employs 52,000 worldwide. Ningke reported that Dow's value-added portfolio in China is becoming Dow's second-largest market achieving 16 percent annual growth in Greater China over the last decade. In considering the goals of China's 12th Five-Year Plan, Dow is seeking to stimulate domestic consumption, develop more consumer electronics, enhance environmental protection, develop renewable energy, improve energy efficiency, conserve water resources, and improve social welfare and farming efficiency.

Ningke described Dow's Yulin Coal to chemical plant, which integrates coal to electricity and coal to chemicals to manufacture high value-added chemicals. The plant is designed with state-of-the-art coal to chemical technologies to achieve cleaner manufacturing, excellence and business sustainability. Past sustainability efforts by Dow include an elm tree planting program in Yulin City, a GHG reduction project in Shaanxi Province initiated in 2009, and partnerships with the Environment Defense Fund and the Shaanxi Department of Agriculture.

CO_2 Management Options for Stationary Sources or Cryogenic Carbon Capture™ Status Report

Presentation Summary

Larry Baxter, professor of chemical engineering at Brigham Young University, presented his work on a carbon capture technology known as Cryogenic Carbon Capture™ (CCC™). The technology has shown successful results at both laboratory and bench scales and has been evaluated by academic and industry experts in the field with positive feedback. The technology, which is under commercialization by Sustainable Energy Solutions (www.sustainablees.com), consumes about 50 percent less energy with half the costs of leading alternatives. In describing the technology, Baxter said CCC™ is a "bolt-on technology with a modest footprint using most equipment common to power plants and other major CO_2 emitters." The technology is suitable to any stationary point source and in addition to capturing CO_2, the process captures So_x, NO_2, Hg, hydrocarbons, HCI, Hf, H_20, and essentially all heavy metals from the flue gas with effectiveness that meets or greatly exceeds that of current technologies. Baxter concluded his talk by providing a status

update of his research project noting that the analysis, modeling, laboratory-scale and bench-scale components are complete, and that the skid-scale CFG and ECL processes are under construction with a pilot-scale system undergoing the design phase.

A New Thermodynamic System for LNG Cold Energy Recovery in its Gasification Process

Presentation Summary

Zhigou Qu, professor of thermo-fluid science and engineering for the Ministry of Education at Xi'an Jiaotong University, discussed a hybrid system utilizing liquid natural gas (LNG) and an organic ranking cycle (ORC). Components of LNG cold energy utilization include the following: air separation, light hydrocarbon separation, power generation, liquid/solid CO_2 production, cryogenic warehousing, seawater desalinization, and cryogenic pulverization. The system applies propane as the working fluid and salt water as the heat source. A heat transfer model was developed to measure evaporation, condensation, and thermodynamics and tested several key parameters including the inlet temperature and mass flow of sea water, the inlet temperature and mass flow of LNG, condensation pressure of propane, and the temperature and heat transfer coefficient distribution.

The results of the testing and research concluded that the proposed system was successful in realizing LNG gasification and cold energy recovery. Qu provided the following conclusions: 1) a one dimensional heat transfer and thermodynamic model for the hybrid system with LNG and ORC for LNG cold energy utilization was proposed; 2) the energy system successfully realized the LNG vaporization and LNG cold energy recovery for net power; 3) the impacts of various parameters on performance of the system were obtained; and 4) the thermal efficiency for ORC was sensitive to sea water inlet temperature and propane condensation pressure.

Coal Pyrolysis and Co-Generation Technology of Heat, Electricity, and Gas Step Combustion Conversion

Presentation Summary

Wang Qinhui, professor at the Institute for Thermal Power Engineering at Zhejiang University, spoke on his research focused on poly-generation technology, technology of hydrogen production from coal and biomass, pollutant control and gas-solid multi-phase flow technologies. He stressed the need to increase the value of coal through improved efficiencies as well as through improved coal pyrolysis and co-generation technologies. Integrated gasification, while more costly than traditional coal combustion, is highly

efficient and increases the economic value of coal. The co-generation technology is a relatively simple system where the produced gas may be used for fuel or chemical synthesis processes and the tar may be processed further for other products such as liquid fuels or hydroxybenzene. The technology uses lower operation requirements for fluidized bed pyrolysis reactors and the process has the ability to use coal with suitable volatile content. Testing of the technology has occurred in a 1megawatt pilot plant, a 12 megawatt demonstration plant, and in 2011, the technology was applied to an existing 300 megawatt industrial demonstration plant -- Xiaolongtang Power Plant. The group has achieved positive results and the developed gas, power, and tar co-generation system is primed for industrial deployment.

Numerical Simulation Research on 600MW Boiler with Different Single Burner Heat Power

Presentation Summary

Zhou Qulan, professor at the Energy and Power Engineering School at Xi'an Jiaotong University and State Key Laboratory of Clean Energy, presented research on the influence of increasing single burner heat power with respect to the growth in pulverized coal utility boiler capacity. Qulan presented modeling results which looked at measuring gas and solid phase flow as well as ignition distances, fuel conversion rates, NO_x emissions, outlet velocity and temperature, and hot corrosion tendency, concluding that single burner power was affected by ignition distance and hot corrosion. A furnace with 48 burners installed in a 600megawatt boiler is optimal.

A Feasibility Study of Geologic CO_2 Sequestration in Ordos Basin, China

Presentation Summary

Lifa Zhou, professor of geology at Northwest University and director of the Shaanxi Provincial Institute of Energy Resources and Chemical Engineering (SPIERCE), reported on findings from his feasibility study of CCS in the Ordovician Majiagou Formation in the Ordos Basin in northern Shaanxi Province. Preliminary simulation results have shown the basin has ideal potential to store the CO_2 currently being emitted from six neighboring coal to liquid facilities outside the city of Yulin. The Ordovician Majiagou Formation is of particular interest for CCS due to its size, location and geologic composition. The Ordos Basin is the second largest sedimentary basin in China with an area of 370,000 km^2. The Basin lies at a depth of 800 – 3500 meters and is located in a monoclinal structure beneath 2,000-meter-thick Mesozoic rock located at depths where pressures and temperatures are well above the supercritical point of CO_2. Zhou said preliminary simulation results show the formation has excellent potential for CCS and could store at least 18Mt/year of CO_2 over a 50-year period.

Development Situation of Coal Processing Industry during the 12th Five-Year period (2011-2015)

Presentation Summary

Gu Zongqin, president of the National Petroleum and Chemical Planning Institute, first defined the Coal Chemical Industry as a coal-based technical process which transfers coal into gas, liquid, solid fuel and chemicals through chemical processes. The industry includes coking, gasification, liquefaction and synthesis chemical processes. China maintains the largest coal chemical industry in the world. It is a priority in the 12th Five-Year period to reform the industrial structure and improve the technology in the coal chemical industry.

During the 11th Five-Year period, China experienced a significant increase in demand for petroleum and thus pushed for the industrialization of new coal processing facilities, including a one megaton direct coal liquefaction facility, three facilities of 160-kiloton indirect coal liquefaction, three large scale coal-to-olefins plants, one facility of 200 kilotons per acre (kt/a) CTG, a number of advanced coal gasification technology plants of coal-based methanol and MTDME, and two 4 billion tons/a and one 1.6 billion tons/a syngas (SNG) project.

Zongqin discussed the advancements being made with demonstration projects in CTL, CTO, CTG, and SNG according to the goals of the 12th Five-Year Plan. There is a focus on industrializing the most advanced technologies in coal-to-liquids, SNG, coal-to-olefin, and coal-ethylene glycol. In addition, the plan seeks to further improve energy transformation efficiencies, further reduce environment impacts and water consumption. Zongqin noted the plan seeks to improve efficiency through industry integration or developing facilities that incorporate the full suite of coal processes from mining and processing to conversion, power generation, and chemical processes all at a large scale. The plan also seeks to achieve the reuse or innocuous treatment of waste residue, waste water, and waste gas as well as near-zero-emissions of main pollutants.

Development priorities of the 12th Five-Year Plan include upgrading the thermodynamic systems, developing coal-polygeneration demonstration projects of Coal-Power-Chemical steam polygeneration and coal hierarchical utilization, and integrating large scale equipment of Coal-to-Liquids, SNG, Coal-to-Olefin, Coal-to-Glycol, Coal Grading Utilization with IGCC or Ultra supercritical power generation system. Additional priorities of the plan include: 1) solving important technical problems related to design and manufacturing of large F-T synthesis slurry bubble column reactors; 2) upgrading SNG demonstration projects to further improve the technology and scale; 3) increasing the gasification pressure in fixed beds to raise the outlet methane content, as well as lower the load on posterior systems; 4) demonstrating efficient waste water treatment and recycling

technology to lower the treatment costs; 5) exploring composite applications of SNG technology to improve resource utilization, efficiency and pollution control levels; 6) demonstrating technology of integrated, co-generation facilities utilizing gas, electricity and chemicals, as well as peak shaving to improve energy efficiency and improve economic returns.

Clean Coal Technical Development Direction and CCUS in China

Presentation Summary

Ren Xiangkun, Director of the Shenhua Company, presented on the critical issues of the 12th Five-Year Plan related to the development of advanced coal technologies. Topics of discussion included coal gasification, coal pyrolysis, coal to liquid fuel, coal to gas, coal to chemicals, clean coal power generation and poly-generations. Xiangkun also detailed the progress of current CCUS studies and projects in China.

Geological CO_2 Storage Feasibility Study: Saline Aquifers and Depleted Oil Fields, Ordos Basin, Shaanxi Province

Presentation Summary

Ron Surdam, director of the University of Wyoming Carbon Management Institute, discussed his Wyoming-based research efforts, noting his group has completed a state-wide assessment of geological CO_2 storage capacities (i.e., storage reservoirs, confining layers, and trapping mechanisms), completed a detailed reservoir characterization of the Rock Springs Uplift (RSU) geological CO_2 storage site, and examined CO_2 storage in depleted oil fields for EOR in the Powder River Basin. Surdam also discussed the progress being made with his group's research efforts in the Ordos Basin, noting that a regional assessment of geological CO_2 storage site capacities has been completed and an assessment of the potential CO_2 storage available in depleted oil fields in the Ordos Basin is ongoing.

While progress in research is being made, Surdam listed several challenges to large-scale geologic carbon storage including managing formation pressure and displaced fluids. Surdam reported that WY-CUSP's research in the Madison Limestone and Weber Sandstone reservoirs have shown that to maintain the integrity of the reservoirs, fluid production must be applied to manage pressure. One of the greatest uncertainties in numerically simulating CO_2 storage processes is characterizing geological heterogeneity in three dimensions. This uncertainty was substantially reduced at the RSU site by integrating 3-D seismic techniques with stratigraphic test well observations. Furthermore the most critical challenge for risk reduction associated with carbon storage on the RSU is the management of displacement fluids.

In his assessment of potential CO_2 storage utilizing depleted oil/gas fields in the Ordos Basin, Surdam said his group is in the process of constructing geological structural and property models

for the selected fields, performing numerical simulations of CO_2 injection for the major reservoirs in the selected fields, and assessing the stranded oil recovery potential and CO_2 storage capacity using the depleted oil/gas fields in the Ordos Basin. The strategy moving forward will entail assembling and compiling publicly available geological, stratigraphic, petrophysical, and petrographic observations for the Ordos Basin, refining regional geological structural models for the Ordos Basin, completing an assessment of the regional CO_2 storage capacity for the major saline aquifers in the basin, selecting specific storage sites for more detailed analysis and evaluation (i.e., site characterization), completing 3-D geological structural models of the selected sites, performing CO_2 injection simulations of selected sites, collecting inventory and prioritizing potential EOR targets in the Ordos Basin, and finally, comparing the Ordos Basin and Wyoming CO_2 storage attributes.

In his concluding remarks, Surdam said the Majiagou Formation in the Ordos Basin has sufficient storage capacity to accommodate decades of CO_2 emissions generated by multiple coal-fired power plants and/or commercial coal to chemical plants. He said the simulation and modelling work (using nine injection wells) shows that at least 9 million tons/year of CO_2 could be injected into the Majiagou Formation near Yulin over a 50-year period. Successful CCS in the Majiagou Formation of Ordos Basin could bring all of the existing coal facilities in the Ordos Basin to "clean coal" standards (a 50 percent reduction in CO_2 emission).

Strengthening Geological Study on CO_2 Sequestration

Presentation Summary

Zeng Rongshu, professor in the Institute of Geology and Geophysics at the Chinese Academy of Sciences, presented his group's research findings on methodologies for evaluating EOR sites and underground reservoirs for potential CO_2 sequestration in China.

The Multi-Scale Science of CO_2 Capture and Storage: from pore scale to regional scale

Presentation Summary

Philip Stauffer, research scientist at the Los Alamos National Laboratory, presented his group's efforts in modeling underground reservoirs for CCS at four scales -- pore, reservoir, site, and region. Understanding the dynamics of each scale is critical to understanding the complexity and potential of these reservoirs. Stauffer presented his group's multi-scale approach using real-world CCS data and real-world CO_2 emissions data from a large U.S. electric utility. At the pore scale, Stauffer's group developed a new method for incorporating pore-scale surface tension effects into a relative permeability model of CO_2-brine multiphase flow at the reservoir scale. His group has benchmarked a reduced complexity model for site-scale analysis against a rigorous physics-based reservoir simulator, and includes new system level considerations including local site-scale pipeline

routing analysis (i.e. reservoir to site scale). Stauffer said his group included the costs associated with brine production and treatment at the site scale which he said is often overlooked in CCS studies. The results of the study suggest that research at one scale is able to inform models at adjacent process scales and that these scale connections can inform policy makers and utility managers of overall system behavior.

Relative Permeability Hysteresis and Permanent Capillary Trapping Characteristics of Supercritical CO_2/Brine Fluid Systems: An Experimental Study at Reservoir Conditions

Presentation Summary

Mohammad Piri, associate professor of petroleum engineering at the University of Wyoming, presented results from his group's study on relative permeability hysteresis and permanent capillary trapping characteristics of supercritical CO_2/brine fluid systems. Piri said his group performed "unsteady- and steady-state flow experiments in three different sandstone rock samples, i.e. low- and high-permeability Berea and Nugget, and results indicate that very promising fractions (about 50 - 83 percent) of the initial CO_2 saturation can be permanently trapped."

Pre-sequestration Geological and Geophysical Characterization for ECBM-CCS Site Selection

Presentation Summary

Yang Ruizhau, senior engineer at China University of Mining and Technology, presented his group's research findings, which tested methodologies and techniques for interpreting seismic attributes. Ruizhau said the group examined a variety of faults and fractures found in underground reservoirs to assess potential impacts on storage of CO_2. Ruizhau said his group's research results will help to reduce the risks of enhanced coalbed methane recovery – CCS (ECBM-CCS) site selection.

Integration of Enhanced Oil Recovery with CO_2 Storage in Mature Oil Fields of the Ordos Basin, China: Opportunities and Challenges

Presentation Summary

Zunsheng Jiao, chief geologist at the University of Wyoming Carbon Management Institute, first discussed accomplishments in CO_2 capture and EOR applications in Wyoming. Jiao said his group has developed an integrated project of CO_2-EOR and geological storage. He discussed opportunities for CO_2-EOR in the Ordos Basin, China.

Noting the great potential for CO_2-EOR in the Ordos Basin, Jiao said the area maintains capture-ready, cost affordable CO_2 sources and favorable environments for applying the integrated approach to CO_2 EOR/geological storage. Challenges for CO_2 EOR/storage in the Ordos Basin include low reservoir pressure, low porosity, low permeability, high reservoir heterogeneity, and absent infrastructures.

Jiao provided details about the favorable potential for integrated CO_2-EOR in the Ordos Basin, noting approximately 150 candidate Minnelusa oil fields appear ideal for CO_2 miscible flooding as many have gone through the secondary recovery water flood stage. The estimated recoverable oil from CO_2 flooding in the Ordos Basin could amount to 180 million barrels or approximately $14.4 billion. Based on experiences with CO_2 projects in Wyoming, Jiao said roughly two-thirds of the CO_2 in the process is recycled and about one third of the CO_2 stays in the reservoir. Jiao concluded his talk by discussing the challenges that need to be addressed to move forward with CO_2-EOR and geological storage in the Ordos Basin. The following steps must be accomplished: 1) screening of reservoirs and targeted pay zones; 2) 3-D geological modeling; 3) reservoir hydraulic modeling; 4) lab CO_2 displacement experiments; 5) compositional CO_2 coreflood simulations; 6) compositional CO_2 reservoir simulations; 7) economic analysis; and 8) CO_2-EOR project implementation design.

Measurement, Monitoring and Verification of the First CCS-EOR project in Jingbian Field, Shaanxi

Presentation Summary

Ma Jinfeng, professor in the Department of Geology at Northwest University, presented his group's research on evaluating the success of the first CCS-EOR project in Jingbian Field, Shaanxi Province, along with the Ministry of Science and Technology of China, the Shaanxi Provincial Government, Shaanxi Yanchang Petroleum Co., Ltd. The CCS-EOR project captures CO_2 from the production of 200,000 tons of methanol and 200,000 tons of acetic acid and transports the CO_2 to Jingbian Field 120km away. According to Jinfeng, the project is now collecting 40,000 tons of CO_2 with the capability of collecting 50,000 tons per year. The group is in the early stages of measuring, monitoring, and verifying (MMV) the project.

CO_2 Utilization using Microalgae

Presentation Summary

Don Challman, associate director and general manager at University of Kentucky's Center for Applied Energy Research, presented his group's development of a modular, scalable, minimal-cost photo bioreactor (PBR) system to facilitate the cultivation of

microalgae using power plant flue gas as the CO_2 source. The group's research efforts have led to the development and ongoing deployment of a pilot-scale PBR system at Duke Energy's East Bend power plant in Kentucky. At site, the group is focused on improving process development, power plant integration, and improving implementation strategies to increase algae growth rate. Challman detailed the challenges that need to be addressed before large-scale adoption of microalgae for CO_2 sequestration can be realized. They are the need to: 1) produce biomass at scales in excess of current reactors; 2) scale-up issues related to the continuous cultivation, harvest, and maintenance of microalgae; 3) complete long-term growth studies at scale to determine seasonal culture variations and accumulations of undesirable compounds, and 4) improve operational power plants' integration processes and realize opportunities for cost reductions.

Challman described his group's main research objectives and recent research highlights. The first of four objectives currently being analyzed deals with identifying ideal algae strains for summer and winter months. The next is to optimize the culturing process and technology. The third objective is to identify and test possible co-products of the algae process including the potential to create fuels and animal products. The final objective is to develop a technology-economic model to estimate the overall cost of CO_2 fixation and utilization at various scales. Among the highlights of the research project's recent efforts are testing 150 candidate algae strains to find promising results in a strain of *Scenedesmus,* a strain native to Kentucky. Testing for a winter strain is currently in progress. The group has also made strides in designing and developing a low-cost PBR with advanced components and the group has been successful in increasing overall algae productivity levels in its system. Looking forward, the group will further refine its PBR design, conduct lab-scale nutrient studies to determine the potential role of micronutrients in the process, and begin generating data for their techno-economic model.

Coal, Carbon, and Consequences

Presentation Summary

Thomas Lubnau, Wyoming Representative for House District 31, discussed the increasing demand for energy globally and the importance of working together to find solutions to energy shortages.

Carbon Regulation in the United States and Wyoming: A Comparative Overview

Presentation Summary

Lynne Boomgaarden, Partner at Belcher & Boomgaarden LLP., discussed the regulatory environment surrounding carbon emissions and CCUS at the federal and state levels. Boomgaarden noted that the 111th U.S. Congress was not successful in passing comprehensive GHG legislation; however, several pieces of pending legislation in the 112th

U.S. Congress deal with increasing or prohibiting carbon emission controls. The proposals that could increase carbon emission controls are: 1) Requiring electric utilities to obtain a percentage of such electric energy from clean energy [S. 214]); 2) Imposing a $10/ton excise tax on the carbon content of any taxable fuel [H.R. 3242]; 3) Expanding the tax credit for new qualified plug-in electric drive vehicles [S. 1602]; 4) Requiring the Secretary of Commerce to establish a Clean Energy Technology Manufacturing and Export Assistance Program [S. 1586]; and/or 5) Establishing in the Department of Energy the Clean Energy Deployment Administration [S. 1510]. Legislation that would prohibit regulation on carbon emissions include: 1) Repealing the tax credit for carbon dioxide sequestration [S. 2064] [H.R. 3308]; 2) Eliminating appropriations for grants to communities to develop plans and demonstrate and implement projects which reduce greenhouse gas emissions and prohibit EPA from expending funds for purpose of enforcing or promulgating regulation of greenhouse gases [H.R. 1]; and/or 3) Amending the Clean Air Act to exclude CO_2 from the definition of "air pollutant." [H.R. 97]. Boomgaarden said she did not expect any substantial legislation to pass in this election year.

Boomgaarden described the sequence of events that led to current federal carbon emission controls. In 2007the U.S. Supreme Court concluded that the U.S. Environmental Protection Agency (EPA) would be authorized to regulate carbon dioxide emissions under the Clean Air Act if an endangerment determination is made. That determination was made in 2009 when the EPA determined that carbon dioxide emissions "may reasonably be anticipated to endanger public health or welfare" 74 Fed. Reg. 66496 Dec. 15, 2009. In 2010 the EPA began requiring states to regulate carbon dioxide emissions, adopting a threshold of 25,000 tons per year for stationary sources subject to regulation (75 Fed. Reg. 17004, April 2, 2010; 75 Fed. Reg. 31514, June 3, 2010). Also at this time the EPA recognized CCUS as a pollution control technology which emitters could select for emissions reduction.

In discussing the regulatory environment in Wyoming, Boomgaarden noted the state has been a national leader in developing legislation related to the geologic storage of carbon emissions. This legislation, which has provided definitions and clarified surface and mineral rights issues, has been useful in providing a framework for the industry in Wyoming. Wyoming has invested millions of dollars for research into CCUS technology. With regard to greenhouse gas regulations, however, Boomgaarden explained that Wyoming has maintained a guarded approach to federal and state regulation.

International Policies that Promote Carbon Capture and the Influence on Technology Choice

Presentation Summary

Sarah Forbes, senior associate, Climate and Energy Program for the World Resources Institute in Washington, D.C., discussed why implementing effective CCS policies is critical to deploying CCS technologies. Forbes said effective policies will need to "reduce capital and operating cost associated with the CCS process, create enabling frameworks

and experiences with CCS, and require action." Creating policies such as tax incentives and/or loan guarantees for CCS would help reduce capital and operating costs and help move projects forward. In addition policies that facilitate infrastructure investments and grants for research and development will allow for more opportunities for CCS deployment. Creating and implementing environmental regulatory frameworks will further expedite the process while maintaining environmental regulatory integrity. The final policy arena which Forbes recommends be developed and implemented are policies that require action such as putting a moratorium on coal without CCS or requiring power plants to adhere to performance standards. Forbes said each approach to policy development will be most effective in deploying CCS technologies if used together.

Australian R&D Supporting the Transition to High Efficiency, Low Emissions Energy Technologies

Presentation Summary

Daniel Roberts, senior research scientist and research group leader for CSIRO Energy Technology, discussed the technology developments and research needed in the areas of efficiency, cost reductions and emissions mitigation in coal utilization. Roberts said current CO_2 capture technologies increase costs and reduce efficiency; therefore developing higher-efficiency technologies for CO_2 capture is essential. The efficiency levels of three options are: 1) retrofitting fossil fuel technologies with post-combustion capture [PCC] (32-37 percent efficiency); 2) IGCC with pre-combustion integrated capture (38-45 percent efficiency), and 3) advanced, novel coal technologies such as direct injection coal engine [DICE >50 percent efficiency] and/or direct carbon fuel cells [DCFC 65-70 percent efficiency]. Gasification could be used for a range of applications producing end products such as diesel, ammonia, methane to gasoline (MTG), olefins, fuel cells, and other chemicals.

Roberts detail the coal gasification research topics of central focus in Australia. To improve the understanding of coal performance in gasification technologies, CSIRO is focusing on new technologies opportunities for Australian coal, implementing advanced coal technologies, and developing high efficiency IGCC-CCS systems. Roberts emphasized the importance of efficiency and cost-reducing technology developments in syngas conversion and gas separation technologies to better facilitate CO_2 capture and hydrogen production.

The Application of Heirarchical Structure Fluidized Bed Reactor in Coal Chemical Industry

Presentation Summary

Wei Fei, professor in the Department of Chemical Engineering at Tsinghua University, discussed the feasibility of applying a hierarchical structure fluidized bed reactor to coal conversion processes (particularly coal to olefins) to increase system efficiency.

Hybrid nuclear-fossil systems for low-CO_2 production of synthetic fuels

Presentation Summary

Robert Cherry, senior research engineer at Idaho National Laboratory, discussed his group's research in the development of hybrid energy systems (HES) for the production of synthetic fuels with low CO_2 output. In the production of synthetic hydrocarbon vehicle fuels, there is no requirement that all three inputs come from a fossil fuel feed stock. Combining, for example, coal as the carbon source, water as the hydrogen source, and nuclear energy, a hybrid system is capable of producing fuels with lower CO_2 emissions than current technologies. The benefits of eliminating the oxidation of carbon-containing feedstocks to CO_2 to supply energy include reduced overall emissions of greenhouse gases and other air pollutants such as nitrogen oxide, sulfur dioxide, and mercury, optimal use of both carbon and non-carbon energy sources, and lastly, a hybrid system can better utilize domestic resources for domestic production. Additional advantages of using small (<300 MW) nuclear reactors in HES, include lower capital costs making financing less risky, location of the facility can be where demand is modest or transmission capacity is limited, small scale nuclear can better match the scale of synfuel and chemical processes, and finally, the system can be located on smaller sources of water for cooling.

Coal to EG: Technological Development and Industrial Analysis

Presentation Summary

Ma Xiaoxun, professor in the Department of Biological and Chemical Engineering at Northwest University, discussed the ethylene glycol (EG) industry trends in China and globally and presented information on the technological advancements being made to convert the industry from oil utilization to coal utilization. The current process of producing EG from oil is costly, inefficient, and water intensive, whereas coal utilization promises lower costs, lower energy consumption, lower water use, and lower emissions. Xiaoxun said that tremendous market potential exists for further development and deployment of coal to EG technologies in China.

Technology of Coal Tar Hydrogenation to Produce Light Fuel Oil

Presentation Summary

Li Wenhong, professor in the Institute of Chemical Technology at Northwest University, discussed his group's research developing advanced coal-to-fuel technologies. In light of rising costs and demand and diminishing reserves of oil, using coal to produce fuel will be essential. There are several methods for converting coal to oil including indirect liquefaction, direct liquefaction, and coal tar hydrogenation. Of these methods coal tar hydrogenation technologies are still under development. Wenhong's research group is focused specifically on the hydrogenation process of coal-based heavy oil as well as catalyst development. The group has been successful in creating yields of clean light fuel oil from tar hydrogenation in the 90 percent range. Wenhong said the technology has been run at demonstration size and is now in the first trial stages of industrial production.

Coal to Liquid and Chemical Technologies: Current Trends, Future Challenges

Presentation Summary

Will Latta, managing director for LP Amina, discussed the company's research and development efforts in coal-to-chemical technologies. Latta said the company is paying particular attention to innovations that address carbon emissions and efficiency. Latta presented information on promising trends in the rapidly expanding industry of coal to chemicals. Latta described several LP Amina poly-generation projects that are in the development stages.

Field Tour Overview

The field tours took place in Yulin in northern Shaanxi Province. This region is home to the Shenfu Coal Field which maintains the seventh-largest coal reserves in the world (280 billion tons estimated coal reserves). This region of northern Shaanxi Province, along with portions of Shanxi and Gansu provinces and the Ningxia Hui and Inner Mongolia autonomous regions, is home to the Ordos Basin which is a 370,000 km^2 basin rich in oil, coal, and natural gas reserves. The Ordos Basin is estimated to maintain 4.2 trillion cubic meters of natural gas reserves, 600M tons of oil reserves, and 26 percent of the total reserves of halite in China. Several co- and poly-generation coal facilities were visited during the field tour and specifications for each facility are listed below.

Wednesday, June 6, 2012

Jingbian Energy and Chemical Industry Park (under construction)

- 40km^2
- Seeking zero emissions
- Using coal, natural gas, and oil
- To be completed in 2013
- Includes Yanchang Oil Group's 180,000 tons methanol plant

- 150,000 tons residual oil pyrolysis
- 600,000 tons Dimethyl ether/methanol to olefins (DMTO)
- 600,000 tons polyethylene plant
- 80,000 tons ethylene plant
- Additional downstream production projects
- Xinyuan Company's 1.1 billion renminbi (RMB) NLG project
- Yanchang Oil Group's investment totals 26.9 billion RMB
- According to Xu Shisen, president of the China Huaneng Group Clean Energy Research Center, the coal-to-olefins demonstration project will be using high pressure gasification technology of coal water mixture, large pipeline coal conveying technology, new generation DMTO technology, and new integrated desulfurization and denitrification technologies. The project, according to Shisen, has bridged the coal and petroleum industries to create value-added olefin.

Acetic Acid Plant of Yanchang (Yu-Heng Industrial Park)

- $102km^2$
- Syn Energy Technology Company's DMTO demonstrative project
- China chemical Yiye Company's 600,000 tones methanol project
- Yanchang Oil Group's 200,000 tons acetic acid project
- 10.1 billion RMB invested
- To be completed by 2020
- Production capacities: 10M tons methanol, 2.6M tones DMTO, 1 ton DME, 900,000 tones acetic acid, 1M tons PVC, 10M tones CTL

Thursday, June 7, 2012

Jinjie Industry Park

- 52 projects
- Coal to chemicals
- Construction materials
- Coal coking
- Electricity (6400MW using 15 million tons coal is largest in Asia)
- 4x125MW exhaust direct air-cooled steam turbine power generation unit
- 2.4 tons industrial waste slag cement
- Livestock product processing, 800,000 tons caustic soda
- 35 billion RMB invested
- 600,000 tons methanol
- Beiyuan Chemical Industry Plant- 1.1M tons PVC
- Tianyuan Chemical Company- 50,000 tons coal-tar lightening w/ medium temperature project
- Guohua Plant in Jinjie

Conference Feedback

- Lynne Boomgaarden, of Belcher & Boomgaarden, said, "I learned of Larry Baxter's work over the years and it's exciting to hear that tests are yielding positive results and progress is being made to move the technology to commercialization. It was also great to see so many students in attendance at the conference as they will be the ones carrying these ideas forward."

- Allison Strube, a UW student attending the conference said, "As a student studying energy policy, it has been beneficial to learn more about the technology and engineering side of the picture. There are many new, advanced coal technologies being applied in China and with any new technology requires the need for new policy. I have learned that to make good energy policies, policymakers must have a good understanding of the technology component."

- Ron Surdam has been traveling to China since 1992. He said building relationships over time is extremely important in China. "You can't just come over to China and expect to make business deals in one trip." Over the past eight years Surdam has worked closely with members of the China Clean Energy Research Center to foster important relationships that he considers are even stronger after this trip. Surdam commented on the outcome of the conference as such: "This third IACTC was outstanding. Most important was the opportunity for Wyoming's political and policy leaders, scientists and engineers to see firsthand the variety of coal conversion facilities in operation throughout Shaanxi Province. In Wyoming, one of the keys to maintaining our vibrant coal industry lies in our ability to utilize coal through value-added, conversion technologies, particularly with respect to coal to transportation fuel conversions."

- There were a variety of coal conversion technologies presented at the conference from hybrid systems to microalgae sequestration, and some were further along in their testing and commercial applications than others. Surdam said, "We will inevitably need a mix of technologies to make this all happen, there is no one-shot solution to these problems."

- Sarah Forbes, Senior Associate, Climate and Energy Program for the World Resources Institute, said she is happy to hear the GreenGen project is making substantial progress, meeting timelines, and yielding results. "It is reassuring to hear these positive updates and it sends a sign to the U.S that its time to adopt and apply these technologies domestically."

- Wyoming Representative and House Majority Leader Thomas Lubnau said "Learning more about the global market trends surrounding the coal industry has been very beneficial for me and other policy makers in attendance at the conference. The exchange of information between our Chinese and Australian counterparts has been invaluable. I believe we have started relationships here in China that will aid

Wyoming's future coal industry."

- Tom Murphy, mayor of Gillette, was greeted and hosted by the mayor of Yulin in the northern portion of Shaanxi province during a two-day field tour of coal conversion facilities in the region Wednesday and Thursday. "As a layman looking in from the outside I am simply in awe at what the brightest and best of both the U.S. and China have done as it relates to energy, specifically coal and its responsible uses." Murphy went on to say, "I believe the efforts of the Wyoming Legislature and the School of Energy Resources is valuable work and I am confident these efforts will help ensure the economic well-being of the State of Wyoming for years to come." Murphy noted that the mayor of Yulin, Lu Zhiyuan, has committed to visit Gillette in the near future to continue making progress with the sister to sister city agreement signed this week at the conference.

- "As a physical chemistry graduate student, the conference was an excellent introduction to advancements in coal technology. Guest speakers discussed a wide spectrum of coal technology topics: Energy policy, extraction of coal via traditional drilling as well as enhanced techniques involving CO_2 injection, separation of fuels and products from raw material, utilization of products as both chemical building blocks and a source for power generation, and treatment and sequestration of byproducts like carbon dioxide and fly ash." --Brandon Scott, PhD candidate at the University of Wyoming

- "Although we are very distant geographically, I was surprised to discover the numerous similarities between Wyoming and the resources-rich regions of China. I was humbled by the hospitality of our hosts and I can't thank all of the people involved enough for the wonderful and life-changing opportunity. Visiting another country is a great way to gain insight on our own image and role in the world. A continued open dialogue between our two countries is the key to reaching our financial, social, and environmental goals." --Brandon Scott, PhD candidate at the University of Wyoming

- "The technology that was most exciting to me is enhanced oil recovery. My career goals consist of promoting and establishing environmental stewardship within the oil and gas industry. The demand for energy is increasing with rising populations, so oil and gas production is necessary to meet this demand. I believe there is a huge capacity and opportunity to pair oil and gas production with carbon capture and sequestration. Since we are producing oil and gas anyway, why not trap CO_2 underground in the process?" -- Carla Moss, University of Wyoming, undergraduate student in Energy Resource Management and Development

- "I found the conference to be a very interesting collaboration between institutions, companies, and governments. Such teamwork and sharing will be crucial to the continued success of not just the coal technology industry, but any industry. I enjoyed the breadth of information covered and the stream-lined way it was

delivered. This being my first international conference, it was enlightening to take part in the lectures by non-English speaking presenters. China, in many ways, is ahead of the U.S. where coal technologies are concerned. The U.S. will never be able to build on the scale and with the budget and timeline that China can. However, the facilities built in the U.S. are cleaner and follow stricter regulations. It's a trade-off that each country has faced, and each has chosen the direction it sees most critical. Wyoming can benefit from a continuing relationship with Chinese coal technology groups and the government in Yulin. As global energy demand grows, the more people working together, on the same page, the better. Building relationships like this one end up helping all parties involved." --Rob Streeter, NSF Fellow, University of Wyoming, Department of Electrical and Computer Engineering

- "Mohammed Piri is doing some exciting work that could really push the frontier of geologic sequestration forward. It was good to see some good basic research being carried out at UW. Likewise, Phil Stuaffer is doing work that is germane to Wyoming and has worked on the Rock Springs uplift." -- Thomas Foulke, senior research scientist, University of Wyoming, Agricultural and Applied Economics

- "My major new observation was confirmation of the amount and variety of coal to fuels or coal to chemicals plants being built in China, not just being talked about as is the case in the US." -- Robert S. Cherry, senior research engineer at INL

- "My immediate impression is that this conference differed from many in that it had elements of good science and public policy – both of which were well received. I appreciated the attendance and participation of the leadership of your state and Shaanxi Province, and those of our and China's national government. From Wyoming's perspective, it's important that the leaders of your state see what their investment in R&D is yielding at the School of Energy Resources [which is great I know], it's important for them to hear from the private sector and other research institutes, and it's important that they see what's going on in Asia. China has become a world leader in CCTs for gasification and advanced power plants – and is making the needed investment in demonstrating technologies for CO_2 capture and sequestration that we aren't doing in the US. We have a whole lot to learn from the Chinese. And, Wyoming has a lot to learn from the strategy of value added industries from coal. Indeed, excellent "fit" between Wyoming and Shaanxi Province-- all the best for your collaboration with China and Australia. Finally, it's never lost on me the importance of teaching and training, and I appreciated the participation of the many University of Wyoming students at the conference and those from the Chinese institutes [nothing like youthful exuberance]. I can think of few things more important than preparing young people to compete in today's global economy, and advancing technology leadership here and abroad. You served them well." -- Donald J. Challman, Associate Director and General Manager, University of Kentucky Center for Applied Energy Research

- Carl Bauer, Energy Resources Council member and energy consultant, said Larry Baxter's technology was unique from other processes currently in use today in that Baxter's technology has the potential to not only capture CO_2 with greater efficiency than what is currently available, but may also be successful at capturing virtually all additional emissions and heavy metals from the combustion of coal.

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